THE AMMONITE-CONODONT ASSOCIATION IN THE MEEKOCERAS BEDS OF NORTHEAST NEVADA

A Thesis

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for the Degree Bachelor of Science

by

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ABSTRACT

An association of ammonites and conodonts was discovered concentrated in thin lenticular limestone beds interbedded with siltstones in the Lower Triassic Thaynes Formation in northeastern Nevada. The mere presence of the limestone within the siltstones is due to current accumulations of shell material and fragments. After considering the various aspects of possible paleobiological relationships (i.e., commensalism, mutualism, parasitism, predation, post mortum relationships, etc.), and examining the distribution and ratios of the elements of multielement and single element conodont apparatuses, it is believed that the ammonite-conodont association results from the same factors which account for the limestone facies, that is, current accumulations of ammonite conchs and conodont elements.

INTRODUCTION

The class association of ammonites and conodonts has long been noted. It is the intent of this paper to establish the reasons for such an association.

Müller(1956, p. 820; 1962, p. W87) noted that conodonts are commonly found associated with cephalopods and are "... particularly abundant in cephalopod-bearing limestones" (1962, p. W87). While working with Lower Triassic rocks in Nevada and Utah, particularly in the Meekoceras beds just north of Montello, Nevada, Clark (1959, p. 305, 306) discovered the association of cephalopods and conodonts. From Lindström(1964, p. 66) there is also mention of and association of conodonts and ammonites. Both Glenister and Klapper (1966, p. 786) and Seddon(1971, p. 726) cite examples from the Canning Basin, Western Australia, where conodont and ammonoid distributions are closely linked. Seddon and Sweet further substantiate this (1971, p. 870). From such studies in the Canning Basin, this observation has been made: " No bed there with abundant ammonoids has as yet failed to yield conodonts" (Seddon and Sweet, 1971, p. 870). They also note, however, that the converse is not true, and not only this, but conodonts are also abundant in strata which may be completely devoid of cephalopods. They further state that the association with ammonoids can be slightly stronger than with nautiloids.

In striving to interpret these associations three workable hypotheses arise: 1) The ammonites and conodonts lived together, 2) There is some kind of death relationship involved, 3) The association is the result of sedimentation phenomena. The first hypothesis encompasses a number of subhypotheses and may be divided into three main categories: negative interactions, neutral interactions, and positive interactions. The negative or antagonistic interactions can be further divided into exploitation involving predation and parasitism. If exploitation, did the ammonites prey upon the conodonts, or

did the conodonts parasitize the ammonites?

Neutral interactions or toleration is really no relationship at all. In this case, it involves the sharing of the same ecologic niche.

Positive or symbiotic interactions include commensalism and mutualism. If commensalism, did the conodonts occupy the living chambers or mantle cavities of ammonites for shelter, or to take advantage of food-bearing currents drawn into the mantle cavity during respiration and locomotion? Or did it go one step further to mutualism, where in exchange for food and shelter, the conodonts fed upon potential parasites to the ammonites or served to groom and clean various areas of the ammonites to prevent bacterial accumulations?

The second hypothesis concerns a death relationship. Did the conodonts utilize the evacuated living chambers of the ammonites for shelter and protection after the ammonites died?

Does the association of ammonites and conodonts result from sedimentation phenomena? Does the association result from selective sorting of similar sized or shaped elements and similar sized or shaped conchs, perhaps of the same specific gravity? Or does their occurrence represent a death assemblage, where upon death the ammonites and conodonts reacted similarly to the action of currents and gravity and accumulated in a shallow protected embayment where they became deposited together?

These are the hypotheses that will be dealt with below in an attempt to account for the ammonite-conodont association. To evaluate the first and second hypotheses and their divisions will involve an examination of the modes of life of the ammonites and conodonts as well as examining the distribution of the conodont elements in relation to the cephalopod conchs. Are there more elements within the living chambers of the ammonites than the surround-

ing matrix? To evaluate sedimentation phenomena, the distribution of the conodont elements is essential in determining whether the apparatuses are complete and represent the entire animal, or whether they represent sorted disarticulated elements.

The association of ammonites and conodonts under consideration in this paper is confined to a two-foot limestone unit in a partial section of the Lower Triassic Thaynes Formation. The stratigraphic section was measured and collected for ammonites by J. W. Collinson, J. B. Marcantel, E. L. Marcantel, and Duncan Foley near Crittenden Springs in Long Canyon about 21 miles northeast of Montello, Nevada, and 5 miles west of the Nevada-Utah border. The geographic location of the stratigraphic section is illustrated in figure 1 and the stratagraphic section is illustrated in figure 3.

Ammonites collected form the Meekoceras unit of the section were initially freed from their matrix and the matrix saved. The freed ammonites in turn were sectioned with a trim saw to expose the body chamber and phragmocone. Invariably the body chamber had been filled with mud which had lithified to micrite, while the phragmocone consisted largely of sparite. The body chambers and any micrite detectable in the phragmocone were separated from the sparry phragmocone with the trim saw. the three samples (matrix, body chamber and micrite, and the sparry phragmocone) were then individually weighed and processed for conodonts using standard conodont procedures described on page 297 of Handbook of Paleontological Techniques. Tables 1, 2, and 4 recap the data obtained from processing the samples. 74JL-1 represents the matrix fraction, 74JL-2 the body chamber and any micrite, and 74JL-3 the sparry phragmocone.

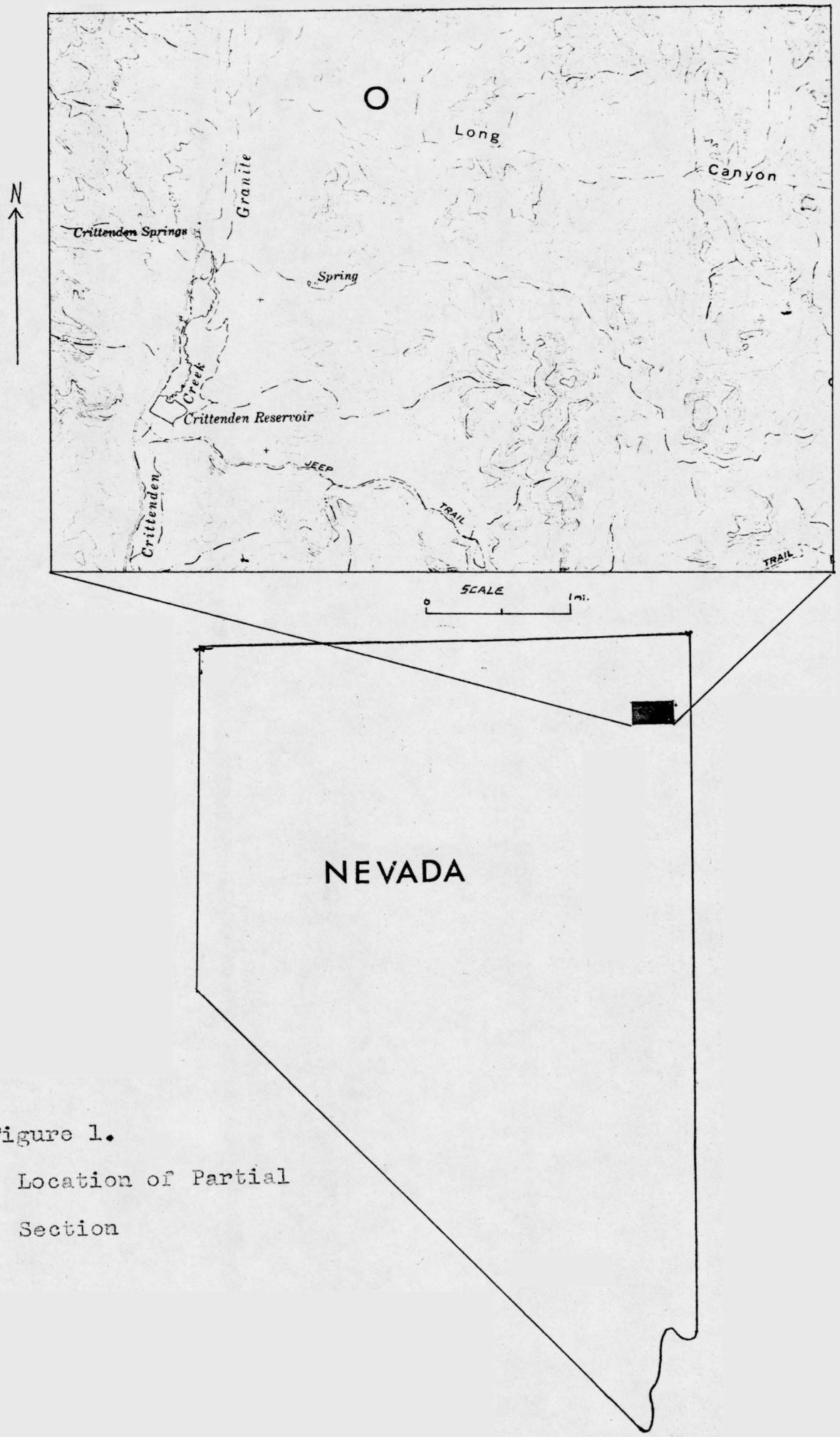


Figure 1.

Location of Partial

Section

I wish to acknowledge the helpful advice and guidance of James W. Collinson, my advisor, who suggested this project for research. The Department of Geology of the Ohio State University generously extended the use of their laboratory facilities and the access to the micropaleontological collection.

STRATIGRAPHIC RELATIONSHIPS

The advent of the ammonite and conodont faunas in eastern Nevada and west-central Utah resulted from a marine transgression in Early Triassic (Smithian) time. During this phase of Early Triassic history, the Thaynes-Moenkopi sea transgressed southwest and westerly from southeast Idaho, inundating west and central Utah and eastern Nevada. As the sea spread, it overlapped the Woodside Shale in Central Utah and onlapped the Permo-Triassic unconformity (figs. 4 and 5) in eastern Nevada. By late Early Triassic (Spathian), the sea had reached its peak in transgression as it impeded the north-south trending Sonoma Orogenic Belt. The above account is taken from Collinson(1974).

An alternating siltstone and limestone facies containg the ammonite-conodont faunas characterizes the lower Thaynes Formation in Long Canyon (fig. 3). The origin of the fine-grained clastics (silt) probably resulted from erosion of the craton (to the east) into the eastern margin of the basin (Collinson, 1974, p. 58). Additional fine-grained clastics may have been contributed by the Sonoma orogeny bordering the basin to the west. In Idaho, Montana, Wyoming, and Utah, the presence of the thin limestone lenses and/or beds within the massive siltstone units is thought to be accounted for by the current accumulations of shell debris in addition to a little quartz silt (Kummel, 1957, p. 456). Pelecypod shells, now characterized largely by molds, could have contributed to the production of limestone when their valves dissolved. The mere presence of the limestone is largely dependent on whether or not shell material is available at the time of lithification. A similar

model may have accounted for, and is now proposed, for the distribution of alternating siltstone and limestone facies in eastern Nevada.

The Thaynes Formation near Crittenden Springs in Long Canyon is predominately poorly exposed. The sequence is composed basically of greenish-gray siltstones interbedded with thin to medium beds of gray limestone. Ammonite-bearing limestone beds are found at two horizons 400 to 500 feet above the base of the section. These beds are lenticular and range from 2 to 10 feet in thickness. Other limestone beds contain abundant shell material including brachiopods, pelecypods and gastropods generally in a lime mud matrix. A detailed measured section is illustrated in figure 3.

The lithology of the two-foot limestone interval may correspond to either beds "a" or "d" of the Crittenden Springs section described by Kummel and Steele(1962). Both beds "a" and "d" are limestones, light gray with limonite flecks or stains. Bed "a" is fine to coarsely crystalline, thick bedded, weathering brown and almost one half or more of the rock unit is composed of cephalopod conchs and fragments. Bed "d" is massive with slabby partings, very fossiliferous with ammonites and contains a few pelecypods. The two-foot limestone unit of the present section (See fig. 3) is medium to coarsely crystalline, medium to dark brown, has abundant ammonites with one half or more of the rock being composed of ammonite conchs. Pelecypods are few, but there are numerous microscopic juvenile gastropods within the unit.

The measured section presented here does not agree with that described by Kummel and Steele(1962). The succession of beds bearing the Meekoceras fauna was previously measured at Crittenden Springs by Steele (Kummel and Steele, 1962, p. 639) and recognized in 175 feet of strata containing three distinct faunal horizons. This same section was observed by Silberling and

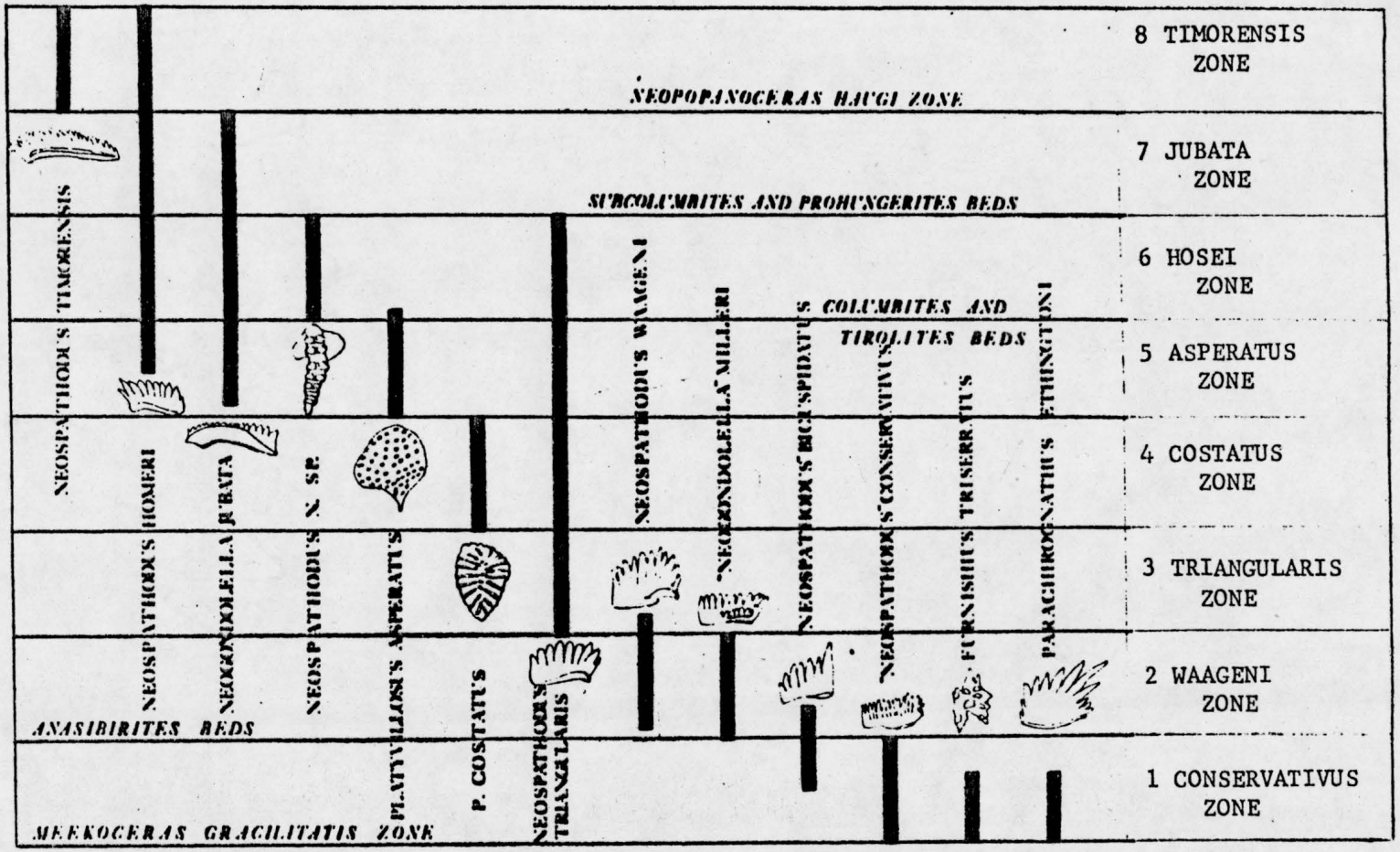
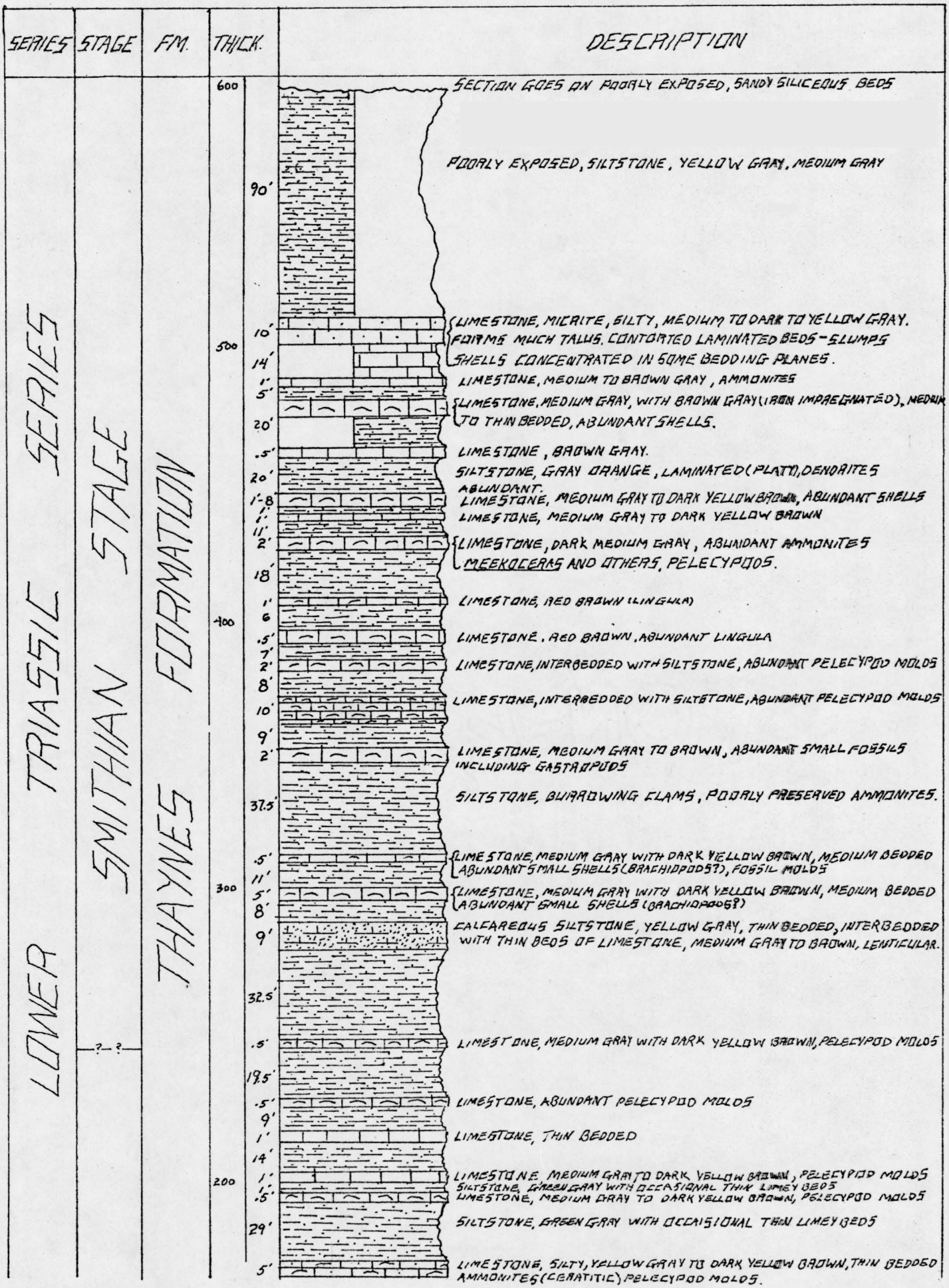


Figure 2. Upper Scythian conodont zones and associated ammonite faunas of the western U.S. Bars indicate ranges of conodont species.
AFTER COLLINSON AND HASENMUELLER 1971).


SERIES
STAGE
FM.
THICK.
DESCRIPTION
LOWER TRIASSIC SERIES
SMITHIAN STAGE
THAYNES FORMATION
?—?
600
500
400
300
200
90'
10'
14'
1'
5'
20'
.5'
20'
1'-8
1'
1'
11'
2'
18'
1'
6
.5'
7'
2'
8'
10'
9'
2'
37.5'
.5'
11'
5'
8'
9'
32.5'
.5'
19.5'
.5'
9'
1'
14'
1'
1'
.5'
29'
5'
SECTION GOES ON POORLY EXPOSED, SANDY SILICEOUS BEDS
POORLY EXPOSED, SILTSTONE, YELLOW GRAY, MEDIUM GRAY
LIMESTONE, MICRITE, SILTY, MEDIUM TO DARK TO YELLOW GRAY. FORMS MUCH TALUS. CONTORTED LAMINATED BEDS - SLUMPS
SHELLS CONCENTRATED IN SOME BEDDING PLANES.
LIMESTONE, MEDIUM TO BROWN GRAY, AMMONITES
LIMESTONE, MEDIUM GRAY, WITH BROWN GRAY (IRON IMPREGNATED), MEDIUM TO THIN BEDDED, ABUNDANT SHELLS.
LIMESTONE, BROWN GRAY.
SILTSTONE, GRAY ORANGE, LAMINATED (PLATY), DENDRITES ABUNDANT.
LIMESTONE, MEDIUM GRAY TO DARK YELLOW BROWN, ABUNDANT SHELLS
LIMESTONE, MEDIUM GRAY TO DARK YELLOW BROWN
LIMESTONE, DARK MEDIUM GRAY, ABUNDANT AMMONITES MEEKOCERAS AND OTHERS, PELECYPODS.
LIMESTONE, RED BROWN (LINGULA)
LIMESTONE. RED BROWN. ABUNDANT LINGULA
LIMESTONE, INTERBEDDED WITH SILTSTONE, ABUNDANT PELECYPOD MOLDS
LIMESTONE, INTERBEDDED WITH SILTSTONE, ABUNDANT PELECYPOD MOLDS
LIMESTONE, MEDIUM GRAY TO BROWN, ABUNDANT SMALL FOSSILS INCLUDING GASTROPODS
SILTSTONE, BURROWING CLAMS, POORLY PRESERVED AMMONITES.
LIMESTONE, MEDIUM GRAY WITH DARK YELLOW BROWN, MEDIUM BEDDED ABUNDANT SMALL SHELLS (BRACHIOPODS?), FOSSIL MOLDS
LIMESTONE, MEDIUM GRAY WITH DARK YELLOW BROWN, MEDIUM BEDDED ABUNDANT SMALL SHELLS (BRACHIOPODS?)
CALCAREOUS SILTSTONE, YELLOW GRAY, THIN BEDDED, INTERBEDDED WITH THIN BEDS OF LIMESTONE, MEDIUM GRAY TO BROWN, LENTICULAR.
LIMESTONE, MEDIUM GRAY WITH DARK YELLOW BROWN, PELECYPOD MOLDS
LIMESTONE, ABUNDANT PELECYPOD MOLDS
LIMESTONE, THIN BEDDED
LIMESTONE, MEDIUM GRAY TO DARK YELLOW BROWN, PELECYPOD MOLDS
SILTSTONE, GREEN GRAY WITH OCCASIONAL THIN LIMEY BEDS
LIMESTONE, MEDIUM GRAY TO DARK YELLOW BROWN, PELECYPOD MOLDS
SILTSTONE, GREEN GRAY WITH OCCASIONAL THIN LIMEY BEDS
LIMESTONE, SILTY, YELLOW GRAY TO DARK YELLOW BROWN, THIN BEDDED AMMONITES (CERATITIC), PELECYPOD MOLDS.

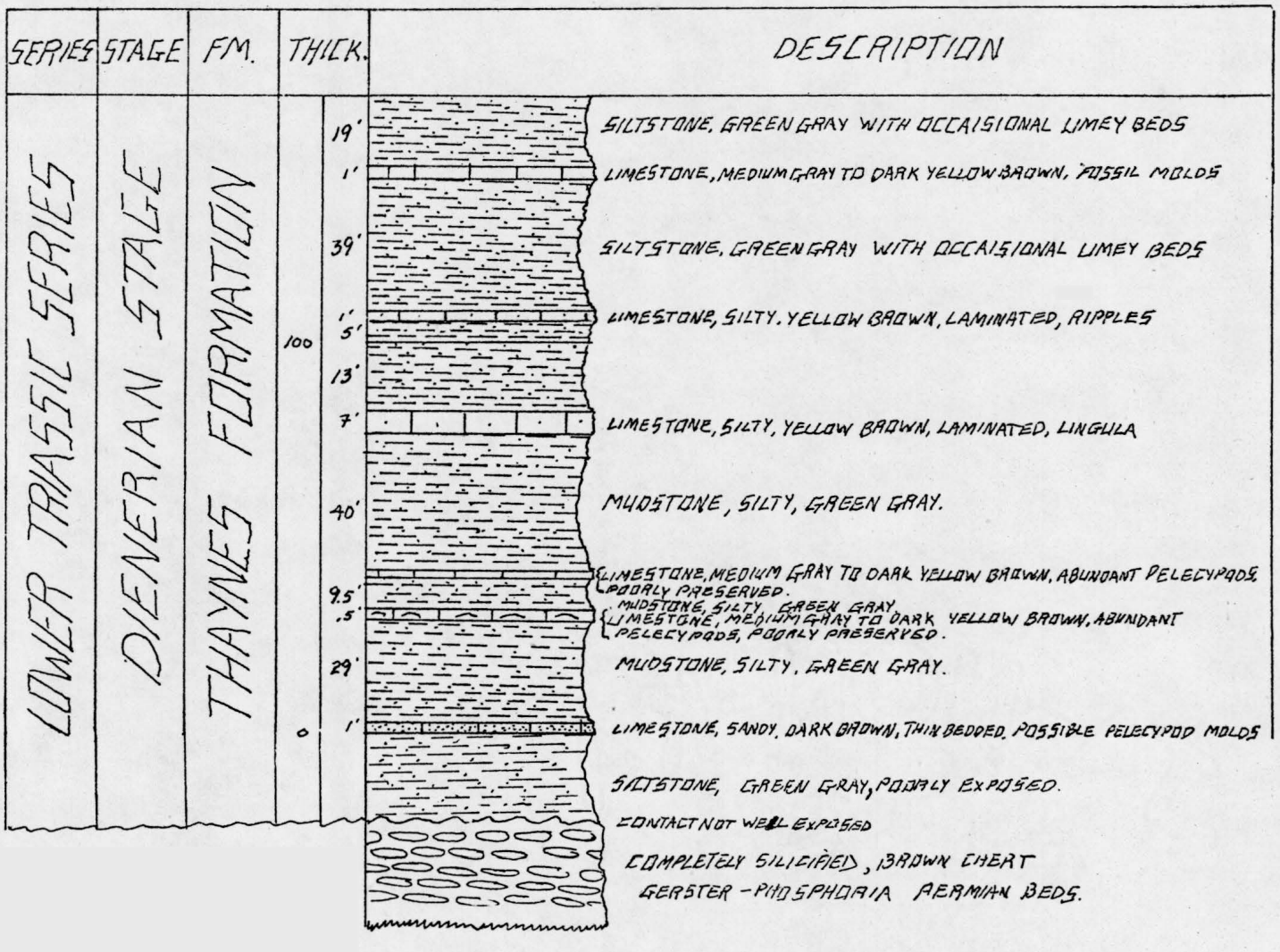


Figure 3. Partial Section
AFTER COLLINSON (FIELD NOTES, 1972)

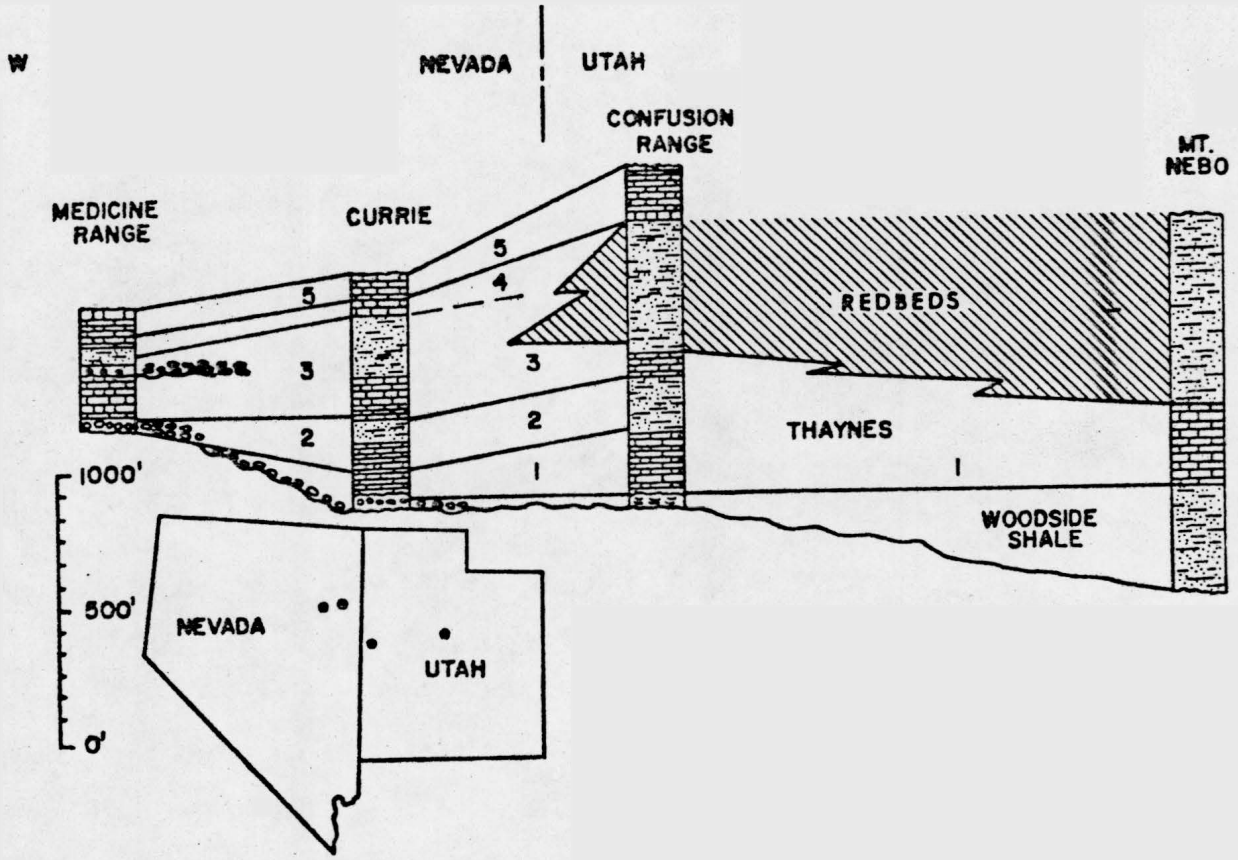


Figure 4a. East-west diagrammatic cross-section across the Smithian-Early Spathian basin. Numbers refer to the conodont zones in figure 2.

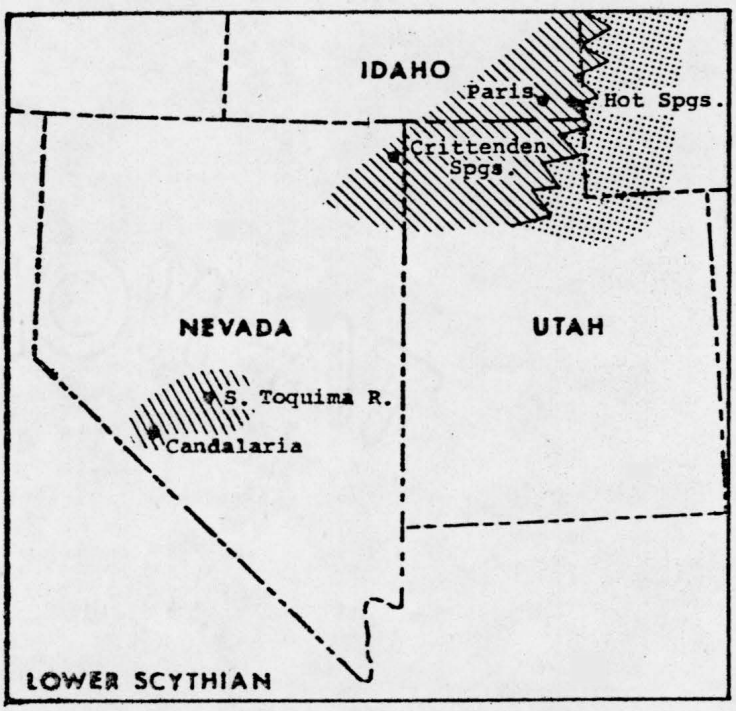
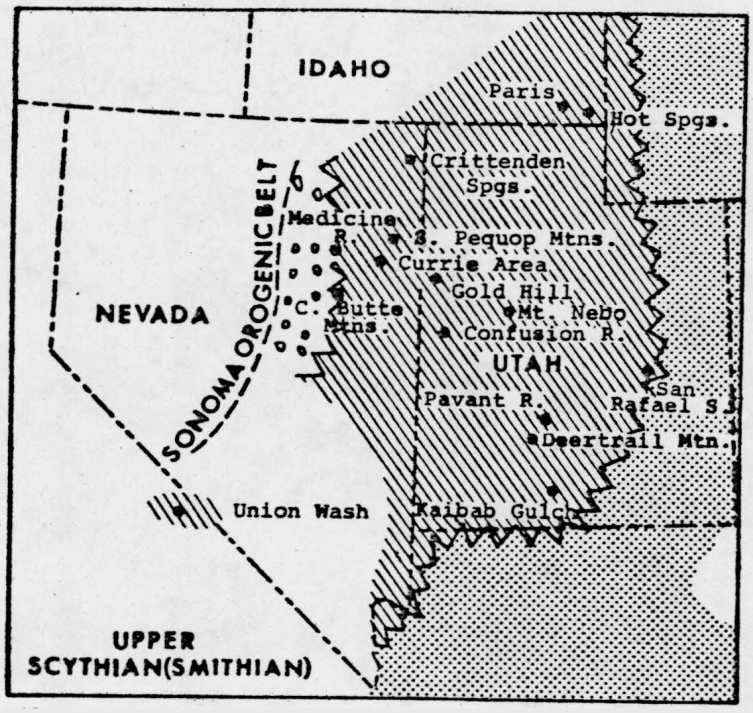


Figure 4b. Map showing present distribution of marine (diagonal pattern) and continental (dot pattern) facies of the lower Scythian. Conodont localities are indicated by heavy dots.

FIGS. 4a AND 4b AFTER COLLINSON AND HASENMUELLER (1974).



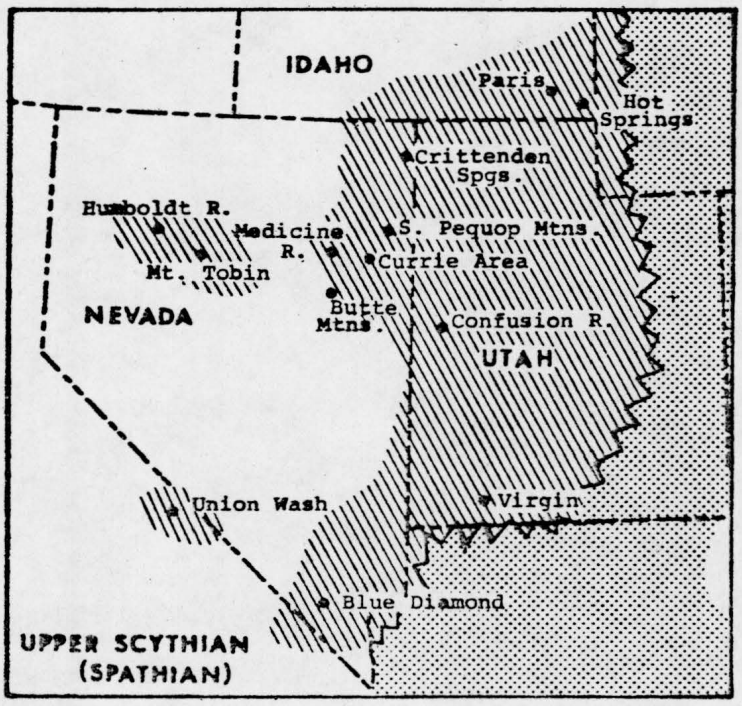


Figure 5. Maps showing present distribution of marine (diagonal pattern), continental (dot pattern), and conglomerate (irregular circles pattern) facies of the upper Scythian. Conodont localities are indicated by heavy dots.
AFTER COLLINSON AND HASENMUELLER (1974).

Tozer(1968) in 1964, but they encountered structural complications. They discovered that these three faunal horizons were not distinct, as depicted by Kummel and Steele, but one in the same caused by repetition of the same part of the section by faulting. The present section was constructed by careful mapping of the described sequence (Collinson, 1974 personal communication). The relationships between Kummel and Steele's Meekoceras beds "a" and "d" and those described here cannot be resolved. However, Kummel and Steele's section probably included repetition of ammonite-bearing beds.

PALEONTOLOGY

Information on the Lower Triassic outcrops near Crittenden Springs was first published by Müller(1956), who described the conodont faunas. Clark(1957, p. 2201,2202; p. 2219, 2220) described the stratigraphy of the locality and later listed a sequence of conodont faunas(1959, p. 306, 307). The Meekoceras fauna has been extensively described by Hyatt and Smith (1905), Smith(1932), and more recently by Kummel and Steele(1962).

The limestone unit of the present section is characterized by the ammonite Meekoceras gracilitatus, which has been assigned a zonal status and includes an accompanying ammonite fauna. The fauna identified in the Meekoceras Zone of this paper is as follows: Dieneroceras spathi Kummel and Steele, [illegible], Dieneroceras knechti (Hyatt and Smith), Preflorianites toulai (Smith), Owenites koeneni Hyatt and Smith, Prosphingites slossi Kummel and Steele, [illegible], Juvenites septentrionalis Smith, Lanceolites compactus Hyatt and Smith, Arctoceras tuberculatum (Smith), and Meekoceras gracilitatus White.

Microscopically, the unit is characterized by the Neospathodus conservativus Zone (Sweet, et. al., 1971)(See fig. 2), the lowest of eight conodont in the Upper Scythian of the western U.S. (Collinson, 1974) and is the corresponding equivalent of the Meekoceras Zone. The zonal indicator Neospathodus conservativus (Müller) is present in the unit, as well as Neospathodus bicuspidatus (Müller),

and the multielement species Ellisonia gradata Sweet, and Ellisonia triassica (Müller). Formerly, lower Triassic zonation has been based on ammonite faunas. This has not always been adequate (particularly in rocks in the Great Basin) due to poor exposure, structural complications, or lack of ammonite faunas. Recently tremendous advances in zonation with conodonts have been made by Sweet(1970) in the Salt Range and the Trans-Indus Ranges of West Pakistan, Hasenmueller(1970) in the Confusion Range of west-central Utah, Sweet et. al. (1971) in the western U.S. and West Pakistan, and Collinson and Hasenmueller (1974) in Nevada, Utah, and Idaho. Thus conodont zonation can be determined within and between the various ammonite zones to allow for a more precise delimitng of zones in lower Triassic rocks.

The Ammonite-Conodont Association. Examining the life modes and habits of ammonites and conodonts should resolve and dismiss those hypotheses which would or would not account for their association. Futhermore, examination of the distribution of the conodont elements relative to their occurrence either within or outside the ammonite conchs, as well as the ratios of the conodont elements to one another, should settle the matter concerning sedimentation phenomena. The regional conditions during the time of the transgression of the Thaynes-Moenkopi Sea mentioned earlier should be kept in mind while looking at the life modes of the ammonites and conodonts.

During the Thaynes transgressive sequence in Long Canyon shallow water conditions probably prevailed. This observation is based on the presence of the inarticulate brachiopod Lingula(See fig. 3), since the living Lingula is confined to tropical and subtropical seas usually less than 40 meters deep (Ager, 1963, p. 38).

Associations of most fossil forms indicate that cephalopods inhabited shallow waters (Miller and Furnish, 1957, p. L2). Despite the fact that some

living nautiloids are found at intermediate and abyssal depths, the majority are most abundant in shallow seas (Sweet, 1964, p. K4). Associations in the rocks found with fossil cephalopods infer that they have always been most abundant in shallow seas on continental shelves (Sweet, 1964, p. K4).

It has long been known that ammonites were probably nektonic, or swimmers. This is based primarily upon analogy with the living Nautilus and the marked bilateral symmetry and lenticular shape (Scott, 1940). The modification of the edges of the foot into tentacles, the parrot-like beak, and the radula mark the Nautilus as a predatory carnivore. Modern Nautilus nocturnally migrates inshore to feed upon small decapod crustaceans and occasionally fish (Black, 1972, p. 78; Stenzel, 1957, p. 1137; Tasch, 1973, p.403). The crop of dissected specimens has often revealed the presence of crustacean fragments (Stenzel, 1957, p. 1137).

In life, the ammonite was capable of buoying up its shell by the secretion of nitrogenous gases from the siphuncle into the various chambers. With the body, the shell, and the gas, the ammonite probably had a specific gravity approximately equal to that of sea water (1.027), again based on analogy with Nautilus. The whole animal and the shell should be approximately in equilibrium with the sea water (Moore, Lalicker, and Fischer, 1952, p. 386). Trueman (1941) has conducted extensive quantitative studies on the buoyancy of ammonites.

Upon death, the soft parts decay and disappear, and the shell is buoyed up by the nitrogenous gases in the chambers. The decaying animal may add even more nitrogenous gas to the conch. Consequently, the shell rises to the surface and is "... carried by currents until waterlogged or washed up on some shore" (Moore, Lalicker, and Fischer, 1952, p. 340). Empty shells of the Nautilus have been found far from the area in which it lives (Stenzel, 1957, p. 1136).

Conodonts, unlike ammonites, have no living counterparts, as of yet known, to analyze. The literature has been proliferated with proposed affinities for conodonts- everything from mollusks, arthropods, annelids, lophophorates, and fish, to even plants has been suggested (Tasch, 1973, p. 809-812). Expansion upon these affinities has necessarily been eliminated from this paper.

Perhaps the best proposal for conodont and paleoecology was put forth by Seddon and Sweet(1971). They proposed as an analogue, the Phylum Chaetognatha. They quote from Hyman(1959) that:

> "The chaetognaths are among the most common planktonic animals, that is, animals that spend their entire existence floating or swimming in the water without relation to the bottom but have such feeble powers of locomotion that they are unable to direct their movements and drift with the tides and currents."

The chaetognaths are three centimeters long, bilaterally symmetrical, worm-like animals. They are equipped with tail fins which serve as excellent floatation devices so that little energy is expended in keeping them afloat. They are, however, capable of quick short bursts of movement. Most chaetognaths seem to inhabit the warm-water epiplanktonic zone(Hickman, 1967, p. 604). As many as 1,000 or more specimens have been recovered from a cubic meter of sea water (Hickman, 1967, p.604). Chaetognaths are equipped with short chitinous teeth making them carnivorous and feeding upon copepods, small worms, larva, eggs, crustaceans and occasionally detrital particles.

This served as perhaps the best analogy until 1969 when the conodont animal was discovered by Melton. In 1969 collaborative research was conducted on the conodont animal which culminated in a report by Melton and Scott in 1973. For the most part, Seddon and Sweet were found to be amazingly accurate in choosing the chaetognaths as an analogue. The animal investigated by Melton and Scott(1973) was indeed bilaterally symmetrical. They possessed a rudder-

fin located at the dorsal posterior end which propelled the animal. Some may have even had a small degree of buoyancy. Melton and Scott visualized the animals as congregating close to the surface and feeding on phytoplankton. They stated that the animals were probably "... swept into estuaries, lagoons, and shallow protected seas where they congregated in great numbers" (Melton and Scott, 1973, p. 55). They place the conodonts in a subphylum of the Phylum Chordata due to the presence of a notochord. The animal did undoubtedly live much like the chaetognaths, as the authors demonstrated in their report. Apparently Melton and Scott could find no evidence for a carnivorous mode of life as in the chaetognaths (at least they made no mention of it).

Looking at these two life modes in light of ammonites and conodonts living together, whether under positive, neutral, or negative interactions, is essential in determining their relationship to one another after death.

First consider the positive interactions. Assuming a commensal situation, did the conodonts inhabit the living chambers or mantle cavities of the ammonites to take refuge and perhaps intercept food-bearing currents drawn into the mantle cavity in the process of respiration? Although the biologic ranges of conodonts and ammonites probably overlapped, the ammonites inhabited comparatively deeper waters distant from the feeding grounds of the conodonts visualized by Melton and Scott. Yet, wouldn't it be possible for the conodonts to feed at night with the ammonites as they made their nocturnal treck shoreward?

Now consider a mutualistic association. In exchange for food and shelter, did the conodonts rid the ammonites of potential parasites or groom and clean the ammonites to prevent bacterial accumulations? Copepods have been recorded as parasitizing the mantle chambers of nautiloids (Stenzel, 1957, p. 1138). If conodonts were by any chance carnivorous like the chaetognaths, they could

indeed induce a mutualistic association by feeding on the copepod parasites while at the same time enjoying the comforts of shelter and protection. In these two symbiotic relationships, two possible solutions have already arisen.

Neutral interactions concerning sharing the same ecologic niche have been partially considered under positive interactions. For the most part, even though the biological ranges somewhat overlap, the ammonites generally inhabited comparatively deeper waters. The greater part of the time, however, the two animals occupy different ecologic niches.

What about negative interactions? Did the ammonites prey upon the conodonts? It would not be too hard to imagine ammonites swimming in shore at night to feed upon conodonts, except that it has already been stated that the main diet of ammonites probably consisted largely of decapod crustaceans. Being equipped with tentacles, beaked jaws, and a radula would allow ammonites to be predatory, and with these structures, would enable ammonites to pursue larger more active prey than conodonts. The absence of cilia in the gills of modern nautiloids and their position in relation to the digestive tract would eliminate ammonites as filter feeders (Which they might well have been had they possessed cilia on their gills and fed upon epiplanktonic organisms).

Did conodonts parasitize the ammonites? If conodonts consumed phytoplankton as Melton and Scott suggest or even if they are carnivorous like the chaetognaths, both feeding habits tend to exclude them as parasites. Parasites rely solely upon their hosts for their life processes. An earlier statement by Seddon and Sweet (p. 2) concerning conodont distribution might infer here that conodonts could not parasitize ammonites or else they should consistently be found together.

In some cases presented of the ammonites and conodonts living together, particularly situations involving symbiotic interactions, little conclusive evidence has been presented as to which of the cases, if any, are correct. It is clear that more information is necessary to settle the matter.

Is there a death relationship involved? Did the conodonts utilize the evacuated living chambers of the ammonites for shelter and protection after the ammonites died? If so, this would classify them as vagile benthonic organisms, which would disagree not only with Melton and Scott's interpretation, but also with the pelagic mode of life of the chaetognath model.

An examination of the distribution of the conodont elements in relation to the ammomite conchs, as well as the ratios of the conodont elements to one another, should clarify the problems incurred not only in proposing that ammonites and conodonts lived together, or that they might be associated due to a death relationship, but also in terms of sedimentation phenomena. A brief account of the history of the generation of the multielement genus Ellisonia might make the concept of the ratios in Tables 3 and 4 more meaningful.

In 1970 while working with conodonts in the Triassic rocks of West Pakistan , Dr. Walter C. Sweet generated a statistical classification for the genus Ellisonia (Sweet, 1970). When the ratios of the various elements were compared to one another, they were found to occur in certain whole number ratios. Two species of Ellisonia were recovered from the Meekoceras-bearing limestone unit from Nevada; these were Ellisonia triassica (Müller) and Ellisonia gradata Sweet (Plate 1, figs. 3-6, and figs. 7-9,respectively; also see Tables 3 and 4). The ratios for these two species as obtained by Sweet are reproduced in Table 3 along with the results of the author. In general, for E. triassica (Müller), the ratios tend to appear as: U<LA<LF<LB, and for E. gradata Sweet as : U<LC<LB<LA. The discrepancy between Sweet's LA and LF elements of E. triassica(Müller) in Table 3 arises because the LA and LF elements are completely morphologically gradational into one another, and the assignment of an element to either LA or LF may at times be arbitrary.

A quantitative analysis of ratios would be a bit presumptuous here due to the absence of sufficient quantities of conodont elements in the case of the author (Sweet recovered 21,000 conodont elements). However, a qualitative comparison of the author's ratios with Sweet's ratios of U, LA, LF, LB, LC elements of E. triassica (Müller) and E. gradata Sweet, show that the various elements are in the proper general ratios to one another and indicate the presence of a multielement conodont species.

Tables 3 and 4 indicate that in each of the three samples (matrix, body chamber, and sparry phragmocone), a respectively decreasing but proportionate distribution is observed from the matrix to the sparry phragmocone. In the positive or negative interactions considered, or in the death relationship for that matter, it would be expected that a concentration of complete multielement and single element conodont species would be found within the living chambers. And in the case of predation, it might be expected that the elements would be disrupted upsetting the ratios. Tables 3 and 4 appear to substantiate this- there is no concentration of conodonts within the ammonite conchs.

The only alternative left to account for the ammonite-conodont association is sedimentation phenomena. Again, the distribution and ratios of conodont elements should settle this. Does the association result from the sorting of similar sized or shaped conodont elements or similar sized or shaped ammonite conchs perhaps of the same specific gravity? Apparently not. Once again Tables 3and 4 indicate the presence of multielement and single element conodont species. The frequency and number of elements in each sample proves that they have not been selectively sorted.

Does the association represent a gathering of ammonite conchs and conodonts after death, where they accumulated in a shallow protected embayment

to become deposited together? It was noted earlier that upon death the soft parts of the ammonites decayed and their shells were capable of drifting with the currents. It was also noted by Melton and Scott that the conodonts probably congregated in great numbers near the surface and were capable of being swept into shallow protected bodies of water.

The presence of the two-foot Meekoceras-bearing limestone unit in Long Canyon may be attributed to the collection of ammonite conchs after death. As mentioned earlier, the current accumulations of shell debris were thought to have accounted for the formation of thin limestone beds or lenses in Idaho, Montana, Wyoming, and Utah (Kummel, 1957). In the model proposed for Long Canyon, Meekoceras ammonite faunas may have been carried, though not necessarily a great distance, into shallow waters where they may have become either water-saturated or entrapped by some structural barrier and eventually deposited. Preservation and orientation of the ammonites suggest that the current need not necessarily have been a strong one. The larger ammonites generally lie parallel to the bedding planes, while the smaller ones have a more random orientation and tend to lie between the larger ammonites. The conodonts, being pelagic (or planktonic) in nature, may have been swept (either before or after death) into shallow water or an embayment with the ammonites by currents or a transgressing sea (in this case the Thaynes-Moenkopi Sea). Upon death, they settled to the bottom, some being swept into the evacuated body chambers of the ammonites. The distribution and ratios of the conodont elements and the orientation of the ammonites plus the overall good preservation of all the fossils in the Meekoceras unit, suggest that the currents which brought these faunas into the Long Canyon area were fairly gentle.

CONCLUSIONS

All evidence for the ammonite-conodont association, at least in the case of the lower Triassic rocks of the Long Canyon area, supports the hypothesis of a thanatocoenose, i.e., a death assemblage. Both animals were allochthonously carried from their native waters by currents or a transgressing sea into shallow water or an embayment, and gently came to rest upon the substrate. Later they became lithified into the two-foot limestone unit characterized by the Meekoceras gracilitatus and Neospathodus conservativus faunas.

SYSTEMATIC PALEONTOLOGY

Neospathodus conservativus (Müller)

Plate 1, fig. 1

Ctenognathus conservativa Müller, n. sp., 1956, p. 821, pl. 95, figs. 25-27.

Neospathodus conservativus (Müller), Sweet, 1971, p. 448, pl. 1, fig. 10.

Description: Characterized by about 12 anteriorly inclined denticles which are compressed laterally, and which are fused near the basal surface, but become discrete near the tips. The basal surface is characterized by a slightly undulating margin.

Remarks: *N. conservativus* is the zonal indicator for the rocks studied in the Long Valley area.

Materials: 32 elements were recovered from the samples. Distribution of these elements is indicated in Table 4.

Neospathodus bicuspidatus (Müller), 1956

Plate 1, fig. 2

Neoprioniodus bicuspidatus Müller, 1956, p. 828-829, pl. 95, figs. 14-17; Igo and Koike, 1956, p. 11-12, pl. 2, figs. 7, (8?), (9?), *non* fig. 6 = *Neospathodus bransoni* (Müller).

Neospathodus bicuspidatus (Müller), 1956, Hasenmueller, 1970, pl. II, fig. 9.

Description: The cusp is flanked anteriorly by a denticle which may equal or dwarf the main cusp. The cusp, as well as the remaining denticles, numbering about 9, decrease in size anteriorly. The basal surface is characterized by a broad flange and a basal cavity with an anterior groove.

Remarks: The basal surface may or may not be arched in the specimens from the Long Canyon locality.

Materials: 18 elements were recovered from the samples. Distribution of these elements is indicated in Table 4.

Ellisonia triassica (Müller), 1956

Plate 1, figs. 3-6

Ellisonia triassica Müller, 1956, p. 822, pl. 96, fig. 12-14; Sweet, 1970, pl. 5, figs. 9, 13-15, 17, 18, 20-22; Hasenmueller, 1970, pl. I, figs. 5-10.

Hibardella subsymmetrica Müller, 1956, p. 825-826, pl. 96, figs. 11.

Hindeodella nevadensis Müller, 1956, p. 826, pl. 96, figs. 2, 3; Igo and Koike, 1965, p. 10, pl. 2, figs. 4, 5; Bender and Stoppel, 1965, p. 343, pl. 15 figs. 1, 3, 4, (2?), (4?); Bender, 1967?, p. 510-511, pl. LIX II, figs. 19, 21, 22, pl. LIX III, fig. 1.

Hindeodella raridenticulata Müller, 1956, p. 826, pl. 96, fig. 1.

Lonchodina triassica Müller, 1956, p. 828, pl. 96, fig. 10.

Lonchodina nevadensis Müller, 1956, p. 827, pl. 96, fig. 7; Igo and Koike, 1965, p. 13, pl. 2, fig. 20.

Lonchodus sp. Müller, 1956, p. 828, pl. 96, fig. 8.

Neoprioniodus unicornis Müller, 1956, p. 829, pl. 95, fig. 18.

?Neoprioniodus sp, Müller, 1956, p. 829, pl. 95, fig. 13.

Ozarkodina? Müller, 1956, p. 830, pl. 95, fig. 23, pl. 96, fig. 18.

Lonchodina mulleri Tatge, 1956, p. 133, pl. 5, figs. 15a, 15b; Huckriede, 1958, p. 151-152, pl. 10, figs. 9, 16, 17; Bender, 1967?, p. 512-513, pl. LIX III, figs. 8-11, 16, (2?), (5?), (6?).

Roundya sp. Tatge, 1956, p. 144, pl. 6, fig. p.

Genus indeterminable Müller, 1956, p. 830, pl. 95, figs. 22.

Angulodus bockae Tatge, 1956, p. 129-130, pl. 5, figs. 1-3, (4a,b?).

Lonchodina cf. bockae Tatge, 1956, p. 129-130, pl. 5, fig. 5.

Lonchodina discreta Ulrich and Bassler, Huckriede, 1958, p. 150, pl. 10, figs. 21-25.

Lonchodina sp. Huckreiede, 1958, p. 153, pl. 10, fig. 4.

Hibbardella triassica (Müller), Igo and Koike, 1965, p. 14-15, pl. 2, figs. 13-15.

Roundya sp. Bender and Stoppel, 1965, p. 350, pl. 15, figs. 20a-c.

Description:

U element: Characterized by a long recurved cusp, a long and high posterior process mounted by 5 or 6 discrete denticles projecting posteriorly; and a basal edge which may form a groove or become inverted in larger specimens. The anterior end bears two downward curving anterolateral processes equipped with denticles which are compressed from side to side in younger specimens, but which may be stout in older larger specimens. These denticles recline back towards the posterior process.

LA element: The LA element possesses a posteriorly curving cusp which has lateral costae and a midposterior process or carina at its base. The carina is short and undenticulated. Anterolaterally to the cusp are two downward curving processes of equal length and bearing 3 to 5 denticles which are also posteriorly reclined, and which decline in length distally from the cusp.

LF element: The LF elements intergrade morphologically with the LA elements. The cusp is stout and reclined, with a carinate side that faces posteriorly. Like the LA element, the cusp is flanked by two down curved processes which are the equivalents of the anterolateral processes in the LA element. The shorter anterior process curves anteriorly and laterally and then downward.The shorter process bears 2 to 3 recurved denticles. The other longer posterior process curves laterally and has 3 to 4 discrete denticles. The basal surface in smaller specimens may bear a longitudinal groove but in larger specimens this surface may be inverted. The bow or arch of the downward curving processes of the LF element is not quite as sharp as that of the LA.

LB element: The LB element possesses a similar intergradational morphology with the LF element just as the LF and LA do. In the LB element the basal surface is nearly straight. The cusp is recurved. The LB element very much resembles the U element in denticulation. The LB element has a short anterior process that projects forward and curves laterally. The remaining denticles are recurved and get larger towards the posterior end just like the U element. The basal surface, like that in the LF and U elements has a longitudinal groove in small specimens and an inverted base in the larger ones.

Remarks: The multielement concept and the ratios of the elements has been discussed previously and need not be elaborated upon at this point.

Materials: U elements- 6, LA elements- 9, LF elements- 22, LB elements- 46. The distribution of these elements may be seen in Table 4.

Ellisonia gradata Sweet, 1970

Plate 1, fig. 7-9

Lonchodina latidentata (Tatge) Huckreide, 1958, p. 151, pl. 10, figs. 32, 38, 39.

Roundya n. sp. A. Huckreide, 1958, p. 163, pl. 10, fig. 28.

Ellisonia gradata Sweet, 1970, p. 8, pl. 1,5, 6, 9, pl. 4, fig. 1-8; Hasenmueller, 1970, pl. I, figs. 1-4.

Description:

U element: ---

LA element: The cusp is long and recurved in the LA element. The cusp is flanked by two anterolateral processes of unequal length. The shorter one projects laterally from the cusp, curves downward and anteriorly, bearing 2 to 4 denticles of almost equal length. The longer process projects posteriorly and curves downward bearing 5 to 6 denticles. The denticles on

the shorter process tend to become fused into a single denticle which may equal or exceed the cusp in magnitude. The posterior face of the cusp bears a small undenticulated posterior process. There is a small shallow basal pit existing beneath the cusp.

LB element: The cusp on the LB element is erect. There is a short straight posterior process and a longer anterior process which projects anteriorly from the cusp and down.

LC element: These elements are like the LA elements in their mode of denticulation, but the shorter anterolateral process is deflected to the side and looks "L" - shaped from above or below.

Remarks: Ellisonia gradata specimens were for the most part, were lacking in the samples and hence are poorly representd.

Materials: U elements- 0, LA elements- 4, LB elements- 3, LC elements- 1.

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APPENDIX

Explanation of Tables

Table 1 was drawn up initially from a suggestion by James W. Collinson, in hopes that a relative proportion or ratio could be utilized in the final interpretation. Despite the fact that the figures appear to set up a nice ratio, they are virtually meaningless as far as this report is concerned. The decreasing numbers of conodonts in the matrix, body chamber, and sparry phragmocone, merely result from chance or random distribution. The fact that there are less conodonts in the body chamber than the matrix merely reflects that the body chamber acted as some kind of filter and is nothing more than a function of the diameter of the aperture. The same reasoning can be applied to the sparry phragmocone where the septal necks restrict the influx of any conodonts.

Table 2 is explained in the text under **Introduction** while Table 3 is discussed under Paleontology.

Table 4 is a tabulation of the individual conodont elements- both single and multielement. The column to the far left is the sample number. The column immediately adjacent to the sample is the species. The next columns, to the right of the species, divide the various onodont elements into the proportions or fractions of the speciman still intact. The remainder were pigeon-holed into the fragment category. To determine just how many animals there were, the cusps were counted. This way, an accurate count could be made without counting two fragments from the same speciman.

SPECIES	Ellisonia triassica					Ellisonia gradata			
ELEMENT	U	LA	LF	LB		U	LC	LB	LA
SWEET	1	1.9	1.6	6.1		1	1.9	2.5	3
CLUM	1	1.5	3.7	7.7		-	1	3	4

TABLE 3

SAMPLE	TOTAL WT.	GRAMS REDUCED	WT. NOT DIGESTED	MAGNETIC	NON-MAGNETIC	LIGHT	HEAVY
74JL-1	290 gms.	270.9 gms.	19.1 gms.	8.8 gms.	1.2 gms.	3.6 gms.	12.3gms.
74JL-2	526.5 gms.	505.8 gms.	20.7 gms.	4.2 gms.	0.9 gms.	3.6 gms.	5.1 gms.
74JL-3	564.6 gms.	557.0 gms.	7.6 gms.	1.6 gms.	0.8 gms.	1.9 gms.	2.4 gms.

TABLE 2

SAMPLE	NO. CONODONTS/GM.
74 JL-1	0.23
74 JL-2	0.12
74 JL-3	0.03

TABLE 1

TABLE 4

Sample			0-¼	¼-½	½-¾	¾-1	Frags.	Cusps
74JL-1								
	Neospathodus conservativus		7	4	1	7		18
	Neospathodus bicuspidatus		-	2	3	2		7
	Ellisonia triassica	U	-	1	2	-		3
	" "	LA	-	-	3	-		3
	" "	LF	1	4	3	6		13
	" "	LB	3	5	7	7	44	19
	Ellisonia gradata	U	-	-	-	-		-
	" "	LA	-	-	1	1		2
	" "	LB	-	-	1	-		1
	" "	LC	-	-	-	-		-
74JL-2								
	Neospathodus conservativus		5	4	4	4		11
	Neospathodus bicuspidatus		1	2	2	5		10
	Ellisonia triassica	U	2	-	1	-		3
	" "	LA	1	1	3	1		4
	" "	LF	-	2	2	4		8
	" "	LB	4	7	7	8		21
	Ellisonia gradata	U	-	-	-	-	53	-
	" "	LA	-	-	1	-		1
	" "	LB	-	-	-	2		2
	" "	LC	-	-	1	-		1
74JL-3								
	Neospathodus conservativus		-	1	2	1		3
	Neospathodus bicuspidatus		-	-	-	1		1
	Ellisonia triassica	U	-	-	-	-		-
	" "	LA	-	-	1	1		2
	" "	LF	-	1	-	-		1
	" "	LB	-	2	2	2		6
	Ellisonia gradata	U	-	-	-	-	7	-
	" "	LA	-	-	-	1		1
	" "	LB	-	-	-	-		-
	" "	LC	-	-	-	-		-

LIST OF AMMONITES

Dieneroceras spathi Kummel and Steele,

Dieneroceras knechti (Hyatt and Smith)

Preflorianites toulai (Smith)

Owenites koeneni Hyatt and Smith

Prosphingites slossi Kummel and Steele,

Juvenites septentrionalis Smith

Lanceolites compactus Hyatt and Smith

Aspenites acutus Hyatt and Smith

Arctoceras tuberculatum (Smith)

Meekoceras gracilitatus White

EXPLANATION OF PLATE 1

All specimens are from the Long Valley lacation in northeastern Nevada; all figures 100X.

FIGS. 1. *Neospathodus conservativus* (Müller), sample 74JL-1, lateral view.

2a-b. *Neospathodus bicuspidatus* (Müller), sample 74JL-2, 2a lateral view, 2b, oral view.

3-6. *Ellisonia triassica* (Müller), sample 74JL-1

3a. U element, lateral view

3b. U element, oral view, one of the anterolateral processes has been broken off.

4. LA element, lateral view

5. LF element, lateral view

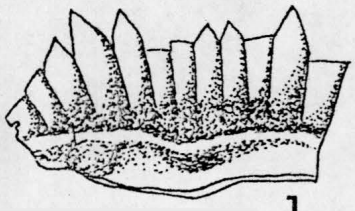
6, LB element, lateral view

7-9 *Ellisonia gradata* Sweet, sample 74JL-2 and 74JL-1

7. LA element, lateral view

8. LB element, lateral view

9. LC element, lateral view.



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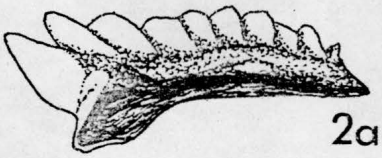

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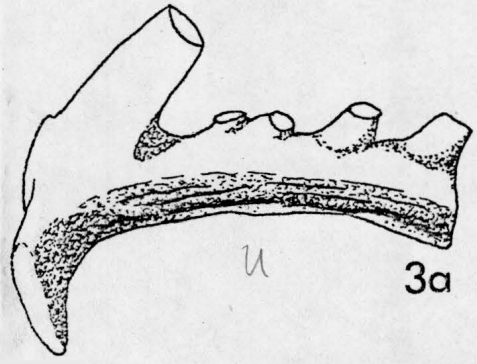
2b



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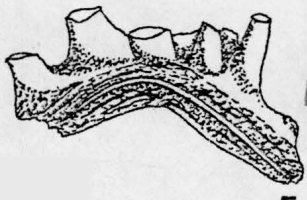

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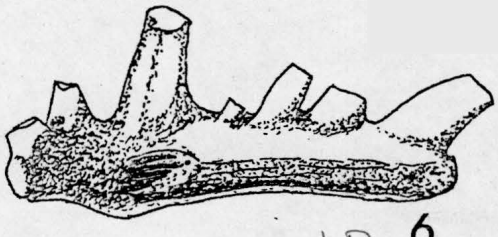

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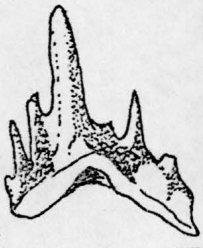

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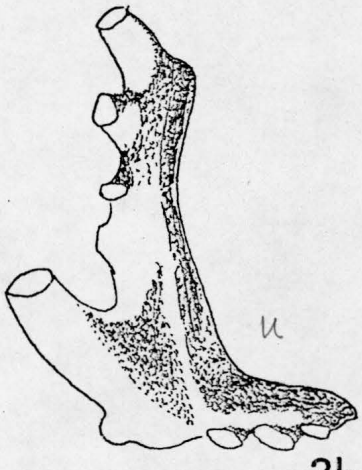

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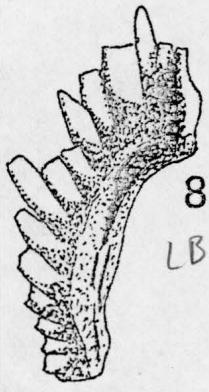

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PLATE I